REPORT
TO
SASKATCHEWAN ENVIRONMENT

KEY LAKE MINING CORPORATION
URANIUM METALLURGICAL COMPLEX

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Consulting Engineer
February, 1984.

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1. INTRODUCTION

On January 18th, 984 Mr. R. Sentis, P.Eng., Director of Saskatchewan Environment approached the author, F. C. Lendrum, Consulting Engineer with regard to personally making an examination of the Key Lake Mining Corporation's mill, where one large spill of contaminated water and seven small spills of mill solutions had taken place since the start of operations in October, 1983. The terms of reference were set out as follows:

TERMS OF REFERENCE

The terms of reference were set out in Agreement No. 65 (83-84) between Saskatchewan Environment and F. Clyde Lendrum Consulting Limited dated January 20, 1984.

1) The contractor will conduct a review of the design and operation of the Key Lake Mining Corporation mill in northern Saskatchewan and provide a report to the Department covering the following areas:

   a) Has the mill design incorporated features to reduce the possibility of upset conditions?
   b) Does the mill design allow for proper contingency procedures during periods of upset conditions?
   c) Is the present mill operation compatible with reducing incidence of upset conditions?

The report is to be completed by February 29th, 1984.

The author visited the Head Office of Key Lake Mining Corporation on January 25th and flew to the mill site January 26th returning to Saskatoon for further interviews with Key Lake senior staff on January 27th. On all occasions, the mining executives and metallurgical staff were most co-operative and helpful in supplying answers to all questions and to conducting the author on a complete and thorough tour of the metallurgical complex with particular emphasis being placed on those areas where spills had occurred.

The Key Lake Mining Corporation's uranium mine and mill are situated some 550 km (341 miles) by air, north-east of Saskatoon, Saskatchewan. The ore body is a high grade uranium ore averaging 2.5% U_3O_8 (48 lbs/ton). The uranium exists principally as uraninite or pitchblende in an unconsolidated sandstone along with a good percentage of clay. The ore body itself was located at the bottom of a small lake and the high grade ore came to surface and was in contact with the waters of the lake. The high grade ore body was, and still is, saturated with ground water. The water table has been lowered, to date, some 24 metres (80 ft.) by wells surrounding the pit. The pit pumps deliver this contaminated water to No. 1 Reservoir, which has a capacity of over 200,000 cubic meters (44,000,000 Imperial Gallons). A second reservoir, half the size, collects the effluent from the tailing pond to be used as recycle or treated prior to release to the environment. It was from No. 2 Reservoir the major spill occurred when the pond overtopped. This report will describe and concentrate on small spills in the mill and the mill operations in general. The report will examine the possibilities for future spills and examine the consequences from major spills such as would occur from the rupturing of tankage.

The Key Lake uranium mill began operations on October 3rd and produced its first yellowcake on October 20th, 1983. The plant operates under a Land Lease arrangement with the Province

of Saskatchewan which requires 50% of personnel in the first year must be Northerners, rising to 60% in year two. The company is licensed to operate by the Atomic Energy Control Board under AECB-MFOL-137-0 dated June 23rd, 1983 and a Certificate of Approval To Operate issued by the Department of the Environment of the Province of Saskatchewan on June 30th, 1983. These licenses have placed discharge limits on effluent of 0.37 Bq/L (10 pCi/L) for radium-226. In the case of the AECB, the regulation is for dissolved radium-226 (i.e. the sample is filtered through a 3 micron filter). Saskatchewan Environment regulation is for "total" radium (i.e. no filtering). This requirement is comparable to the Canadian drinking water standard of 1 Bq/L (27 pCi/L). The Canadian drinking water standard is for total radium-226. The effluent limits for other metals etc. are those set out under the Federal Fisheries Act.

The report will examine the metallurgical process and plant design and follow this description with a discussion of the spills that have taken place in the four months the mill has operated.

2. SUMMARY

1. All spills of an acidic nature in the mill to-date have been small amounts in the CCD or Solution Pretreatment sections. The spills could all be attributed to learning experiences for the mill crews and were not the result of errors in design.

2. Contingency procedures are in place and sumps are capable of holding spills. Spills to-date have really been learning experiences for both mill staff and crew. There are only two areas in the metallurgical complex that have had spills, the CCD and the solution pretreatment circuits. High level alarms and overflows will protect the CCD circuit when clouds of water vapour (Photo 1) obscure solution levels. Changes to the computer program and operation instructions will minimize spills in the solution pretreatment circuit.

3. This report will not discuss the spill of neutral contaminated water from No. 2 Reservoir. This spill is being investigated by others.

4. The housekeeping of the Key Lake mill is exemplary. The cleanliness of the plants including sumps, is shown in Photographs 2, 3 and 4.

5. There are duplicate pipelines on main pulp lines and provision for quick change of pumps to minimize the intensity of an upset.

6. The metallurgical flowsheet is made up of elements of standard unit processes used in the milling of uranium ore.

7. The placing of the asphalt aprons around the metallurgical buildings to direct any spills to No. 2 Reservoir must have a high priority. As soon as temperatures are satisfactory paving should start.

8. The only major change in design contemplated will be converting the secondary crushing from the use of an impact crusher to the use of a Semi-Autogeneous Grinding (SAG) mill. This should simplify handling of the clayey ore and can be done without interfering with present tonnage rates.

9. The monitoring program set out by the AECB and Saskatchewan Environment is very thorough and strict. It not only monitors effluents and water pathways but includes aquatic biota and sediments. Air monitoring is required by Saskatchewan Environment.

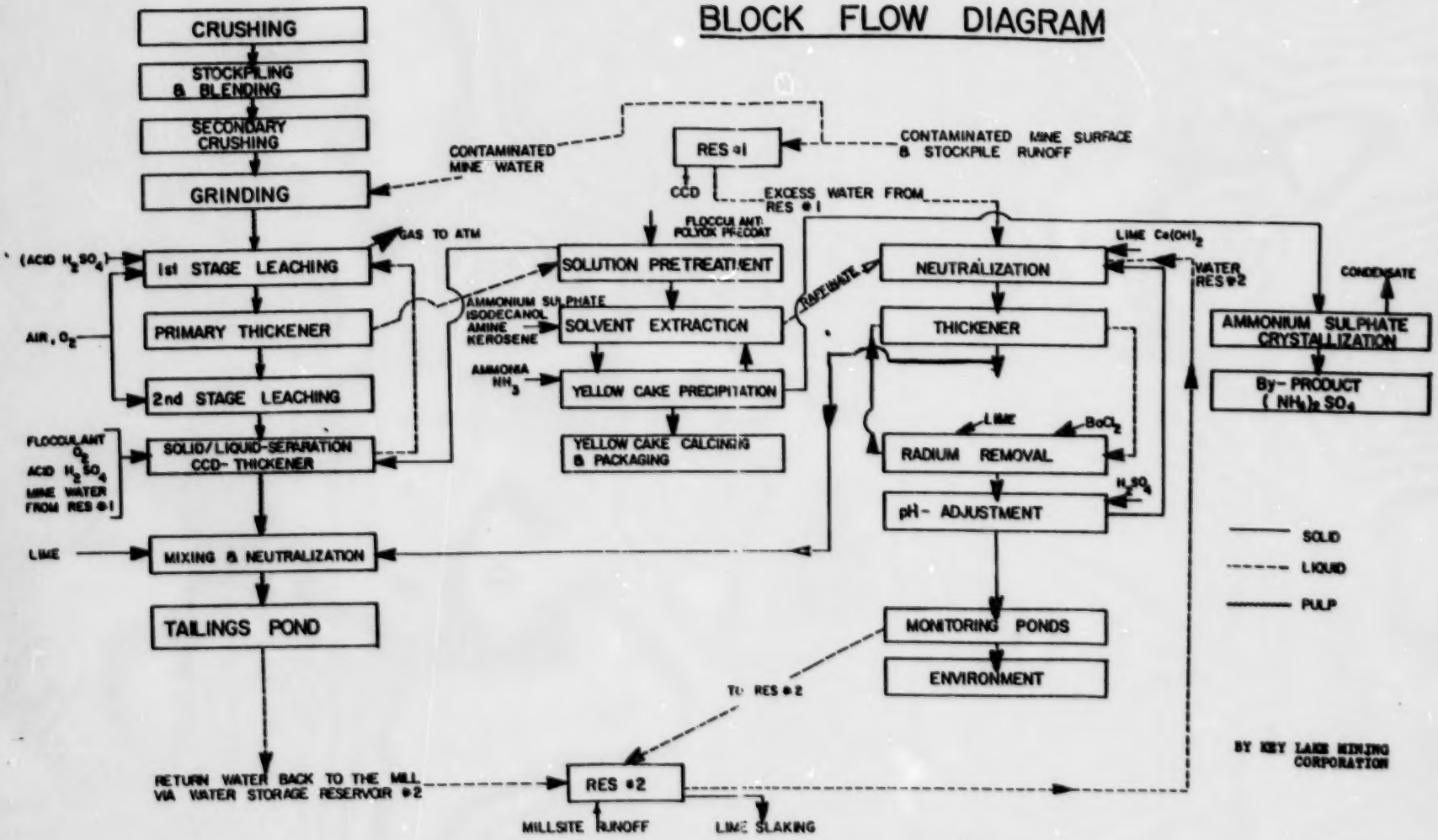
3. PROCESS

When it became obvious that Key Lake had a commercial ore body the company was faced with a metallurgical problem of developing a process for a high grade uranium ore carrying significant amounts of nickel and arsenic. The object was to develop a process using conventional or at least well known variations of standard processes. The process developed by Key Lake is a two stage leach using sulphuric acid as the leaching agent for the uranium. Because uranium must be in the hexavalent stage (U^{+6}) to dissolve in sulphuric acid the quadravalent uranium, (U^{+4}) had to be oxidized using ferric iron and this was carried out using oxygen or air under pressure in the second stage leach. The test work indicated the ore should be ground to -35 mesh in water, prior to leaching with sulphuric acid. The pregnant liquor carrying the uranium would be separated from the ground ore by counter current decantation (CCD). The underflow from the final thickener would be neutralized with lime and sent to the tailings pond.

The pregnant liquor would be removed after the first or primary leach and this high grade solution clarified by thickening, followed by filtration through precoated pressure filters.

The clarified solution would be stripped of its uranium by solvent extraction (SX) using a tertiary amine in kerosene with some isodecanol added to aid phase separation. The uranium enters the organic phase and is stripped from the organic by a solution of ammonium sulphate from which the uranium is precipitated as ammonium diuranate (yellowcake) using ammonia gas. The yellowcake is washed free of ammonium sulphate in a thickener, which returns the concentrated ammonium sulphate solution to solvent extraction, followed by two washing centrifuges. The yellowcake is dried and calcined to remove ammonia prior to shipment to a refinery.

BLOCK FLOW DIAGRAM



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The above are standard uranium metallurgical practices and all unit processes are in use at other uranium plants in Canada and the free world.

The problems of pollution control was attacked from the beginning of metallurgical testing. Make-up water for the process is a combination of pit water, recycle from the tailing pond and internal recycles. The water use system is ultra-conservative and somewhat complex, but in simple language can be described in the following five steps.

1) Contaminated water from the mine, surface and stock piles run-off, is pumped through pipes encased in a utilidor so that leaks to the environment are virtually impossible. This water is used in the grinding circuit with any excess going to Reservoir No. 1. Reservoir No. 1 in the mill area has a capcity of 200,000 cubic metres (44 million Imperial Gallons) and is the source of water entering the mill process via the CCD circuit for washing the extracted uranium from the mill pulp. Excess water is sent directly to the neutralization plant.

2) The tailing disposal system uses a system designed by Knight and Piesold. In this system, the tailings are flooded over a prepared base in thin layers. The tailings settle and the water from the tailings pond returns to Reservoir No. 2. The object of flooding is to produce layers which will form a dense, nearly impervious mat through which water will only penetrate with great difficulty. If

water cannot penetrate the tailings then contaminants within the tailings cannot be leached out and final decommissioning of the piles should be made easier.

3) Reservoir No. 2 collects the mill site run-off. The only use for this water is in lime slaking and the excess is pumped directly to the neutralization plant.

4) Neutralization and radium treatment is carried out in a sophisticated plant using lime to neutralize residual acid and barium chloride to co-precipitate the radium as a (barium/radium) sulphate which is removed and sent to the tailing pond with the solid tailing.

5) The effluent from the neutralization plant which should now be ready for discharge to the environment is sent to one of five holding ponds where the water is analysed to assure it meets the specifications set out by the AECB and Saskatchewan Environment. If the effluent meets the specifications, it is then pumped to the environment via the swamps around Wolf Lake. If it does not meet specifications it is returned to No. 2 Reservoir.

To protect against spills into the environment, in 1984 the company plans to surround the grinding and metallurgical plants with asphalt aprons which will drain to the contaminated water system at the grinding plant and to No. 2 Reservoir at the mill.

4. ENGINEERING DESIGN

While the metallurgical flowsheet is made up of elements of existing flowsheets, the engineering design had to accommodate the blending of an ore that could vary from 0.6% to 40% U_3O_8 into a mill feed that would stay close to 2.5%. A consistent feed is necessary for efficient operation of any leach and solvent extraction circuits within a mill. The design engineers chosen were Wright Engineers Limited of Vancouver, British Columbia, an established engineering company in mill design.

4.1 CRUSHING AND GRINDING

The design parameters set out were a production of 5,443,115 kg. (12×10^6 lbs.) U_3O_8 per year based on a 24 hour operating day, and 330 days per year. The throughput design rate was set at 30 tons/hour or 720 tons/day. To maintain a consistent head assay and at the same time minimize the storage of high grade ore inside a building, the engineers designed a two-stage crush. Ore from the pit is scanned by radiometric scanning of the trucks going to the primary crusher which crushes the ore to approximately -20 cm (-8"). The crushed product is immediately loaded into a second truck for delivery to the stockpile blending area. The stockpile also contains two special piles, a "cobble ore" pile which is low grade ore (0.6% U_3O_8) and a high grade pile which carries extremely high grade ore which will be fed into the mill circuit at a controlled rate. The primary crusher design was set at 350 tons/hour to operate on a 10 hour day to co-ordinate operations with the mine.

For the storage piles, the blended ore is brought by front end loader to a surge bin ahead of an impact crusher. The product from the crusher feeds a 2700 mm ø by 3000 mm (9 ft. ø x 10 ft.) ball mill operated in closed circuit with three Derrick Screens. The oversize returns to the mill and the undersize is dewatered in

a 20 m ø (66 ft. ø) thickener. The thickener overflow returns to the ball mill as grinding solution and the thickener underflow is pumped to the leach plant at 50% solids through a pipe contained within the utilidor. There is standby pipe for use when maintenance is required or in event of emergency.

The crushing and grinding section has had operating difficulties stemming from a misinterpretation of the geological characteristics of the ore. The geological interpretation of this ore body claimed it would contain some 15% monmorillonite clay. When mining started, it was found that the ore section would average 40% and there could be sections that contained 90% clay. With an ore that is situated below the water table and has to be drained to be mined, wet clay has caused handling problems in chutes, the impact crusher and surge bin. To ease these handling problems, the impact crusher was moved ahead in 1982 so that it discharges directly into the ball mill feed chute eliminating the need for a surge bin. This has improved operations but the mill has only operated at a rate of 550 tons/day or about 76% of its design capacity to-date.

To eliminate this operating problem, the company is now investigating the use of a SAG (Semi-Autogenous Grinding) mill which will allow trucks to dump on a 46 cm (18") grizzly and crush only the oversize from the grizzly to -6". The crushed material plus the undersize from the grizzly can be put directly into the SAG mill. The present ball mill will be used to regrind oversize from the Derrick screen should this prove necessary.

A corporate decision is expected shortly and if approval is received, the company believes a change can be made in 1984.

The author went through this plant and in spite of the problems with clay, the plant is clean and the floors are kept free of broken ore. The addition of a SAG mill should eliminate many of the handling problems and make it easier for the crew to maintain the present good housekeeping condition.

4.2 LEACHING

The neutral ground pulp from the grinding plant is pumped through the utilidor to the leach plant and stored in one of four 6.5 m ø (20 ft.) pachuca tanks. These tanks are 13 m (42 ft.) high plus a 5 m (16 ft.) cone. The pachucas are air agitated to keep the ground ore in suspension. The pachucas are set on legs in a sump calculated to hold the contents of more than one tank should it ever become necessary to drain one quickly. Because the pulp is neutral, not acidic, the problem of tank rupture is minimal and normal repairs would be carried out by emptying the tank through the course of normal operations not requiring the sump.

The stored pulp is pumped ahead to the first of four 3m diameter (10 ft ø) leach pachucas where it is diluted from 50% solids to approximately 25% solids with the overflow from No. 1 CCD thickener. The acid level is adjusted to between 14 and 18 gms/Litre (<pH 1) by the addition of 94% sulphuric acid manufactured on site from molten sulphur. These rubber lined pachucas are surrounded by a sump capable of holding the contents of at least two in the unlikely event of a tank failure. Normal maintenance is carried out after the contents of the pachuca are pumped ahead. Because these vessels are rubber lined they are prominently marked with the warning "no welding" as a precaution against fire.
The author examined the sumps of both the neutral and the acid side of the leach circuit and these sumps were clean and contain no solids on the floor. This is another example of good housekeeping by the Key Lake mill staff and crews.

The overflow from the last pachuca drains to the 20 m. diameter (66 ft. ø) primary thickener. The overflow from the primary thickener contains all the solubilized uranium from both the first and second stage leach processes. This pregnant solution moves forward to the solution pretreatment area where it is clarified prior to solvent extraction. The underflow from the pregnant thickener returns to the second stage leach which takes place under air pressure of 65 psi at a nominal 35% solids and a temperature of about 70°C. The compressed air which is used to supply oxygen to oxidize the sulphides will be replaced by pure oxygen when the oxygen plant comes on stream later this year. The discharge from the last pressure vessel is the end of leaching, per se. No. 10 pressure vessel discharges to a let down pachuca prior to being pumped to No. 1 thickener of the CCD section. The overflow from No. 1 thickener is the make-up solution from the first stage leach. Once again, the sump below the pressure vessels will hold the contents of more than one pressure vessel and the floors are steeply sloped so that if a pressure vessel must be drained it can be drained directly by hose to the sump and pumped back into the flow. The sumps of this section were also clean and hosed down.

4.3 COUNTER CURRENT DECANTATION (CCD)

The high uranium content of the ore required eight stages of CCD compared with the usual five in most uranium mills. Three of the in-plant spills have taken place in the CCD circuit. These spills will be discussed in depth in the next chapter but have occurred on shutdowns when an upset condition had taken place. The spills have resulted from overflowing of a thickener tank and could probably be attributed mainly to the inexperience of the mill crews. To protect against this the company will install high level

probes in the thickener tanks which will sound an alarm to warn the operator of possible trouble. The mill staff are now considering an alternate solution of installing overflow pipes on the thickener launders which will drain to pump boxes in the thickener corridor (Photo 3) which runs below the thickeners. This would further minimize the possibility of this type of spill. Because the thickeners are FRP lined, the fusing of overflow pipes into the FRP liners will have to await the warmer weather of spring.

The thickeners are set on compacted fill and are serviced by a central corridor running between and below the thickeners (Photo 3). This corridor has a holding capacity of about 200 m^3. There are also escape ways from under each thickener in the event of a sudden flooding of the corridor. These escape ways exit onto the ashphalt apron around the buildings. The most likely problem with acidic solutions and thickeners is corrosion around the discharge cone on the bottom of the thickener. A sudden rupture would discharge a tank in minutes. To protect against this, Key Lake has fabricated these cones from 316 stainless steel and rubber covered them on the inside. The rubber protects against abrasion from the solids and the stainless steel will prevent the corrosion of the metal cone itself should a pin-hole develop in the rubber. The small spills that have taken place over the top of thickeners have been picked up and taken to the special waste section. When the asphalt terrace has been completed around the thickeners, any spill of this nature would drain or be washed into No. 2 Reservoir. The company plans on putting this asphalt down as soon as weather permits and estimates it will take one month to lay the asphalt.

4.4 PREGNANT SOLUTION PRETREATMENT

The pregnant solution (i.e. overflow from the primary thickener) is adjusted as to pH and clarified in a reactor clarifier

to remove suspended solids before being filtered through three precoat filters operating in parallel. Each filter has an area of 70 m^2 and discharges a clarified pregnant solution ready for solvent extraction.

The pretreatment section has two large storage or surge tanks. These tanks have a capacity of about 12 hours production and the operating instructions are that they are to operate at less than half capacity so the tanks can accommodate at least six hours of surge in event of an upset in the solvent extraction section. This is considered long enough to slow the plant down or bring it to a complete halt should this be required. These tanks have both high level and extra high level alarms to warn operators against over-topping. No spills have occurred because of surges or build-up in the storage capacity.

There have been three spills in the pretreatment section. The first spill in this area, a pressure switch malfunctioned and pregnant solution by-passed on to the floor and 1.1 m^3 (250 Imperial Gallons) overflowed the floor sump and went out the door. The pressure switch was repaired.

In a second spill, a precoat filter went into the regeneration cycle before the previous filter had completed its cycle. This excess of solution overflowed the tank, filled the sump and <0.4 m^3 (100 Imperial Gallons) of pregnant solution flowed out the door. The regeneration cycle starts when the pressure builds up in the tank to a set pressure where the computer starts regeneration of the filter automatically. The computer program has now been rewritten to decree a thirty minute delay between the end of one regeneration cycle and the start of another one. This will protect against two regenerations taking place simultaneously.

The third spill was minor when the reactor clarifier developed a vibration because of an extraneous piece of mild steel became entangled in the mechanism. The machine had to be drained quickly and the solution splashed on the concrete floor and overshot the sump. The drain on the clarifier has now been modified so it discharges directly into the sump.

The company has placed a temporary barrier across the service door and plans to raise the sill of the man door. When the asphalt apron is completed these spills will be directed to No. 2 Reservoir.

4.5 SOLVENT EXTRACTION (SX)

The solvent extraction circuit was designed by Pechiney Uging Kulmann of Paris, France using Krebs equipment. The design is totally enclosed and has the usual automatic fire extinguishing protective equipment used with organic solvents. The physical layout of the plant is shown in Photo 2. The two main streams from the SX plant are the loaded aqueous solution carrying the uranium and the stripped solvent which recycles within the SX building.

4.6 URANIUM PRECIPITATION

The uranium is precipitated from the aqueous ammonium sulphate solution, by the addition of gaseous ammonia as ammonium diuranate or "yellowcake".

The precipitated yellowcake is thickened in a thickener set within its own separate sump in the general sump area. In the event the "yellowcake" thickener has to be repaired, it would be drained into the inner sump. The thickened yellowcake is washed

twice in Bird centrifuges, dried, calcined and packed in drums.

The ammonium sulphate bleed solution is crystallized to produce ammonium sulphate fertilizer.

4.7 TAILING NEUTRALIZATION AND RADIUM REMOVAL

After the uranium has been dissolved and removed, the residual solids must be neutralized and the waste solutions must also be neutralized and the radium-226 removed. There are three major process streams that must be treated.

a) The solid tailing from which the uranium has been removed but which is now an acidic pulp which contains ninety-five percent of the original radium-226 in the ore. The neutralized tailing will be discharged to the tailing pond and the solution from this tailing pond returned to No. 2 Reservoir.

b) The raffinate from the solvent extraction plant is the most contaminated solution stream. This is the uranium pregnant solution from which the uranium has been removed by solvent extraction. The raffinate will contain the remaining radium-226, the dissolved heavy metals, will be acidic and will contain traces of the organic from the solvent extraction plant.

c) The excess mine water from the storage reservoirs. This is mainly ground water that surrounded and saturated the ore body in place. This water is not acidic but it will contain radium-226 and was in contact with the natural waters of Seahorse Lake. This contaminated water is pumped to No. 1 storage pond. This water is used for milling

purposes and will then report with the tailings or as raffinate. The excess must be treated for radium removal before being discharged back to the environment.

There are also a number of minor streams such as:

1) Washdown water from the cleaning of trucks and vehicles used in the pit. This water is drained to a pit and removed by tanker to either the treatment plant or No. 2 Reservoir.
2) Water used to wash miner's boots and the laundry water from washing work clothing also goes to the washdown pit for trucks and is delivered with it to the treatment plant or No. 2 Reservoir.
3) Minor amounts from sumps.
4) Area run-off which flows to No. 2 Reservoir either directly or through pump lines from the grinding plant.

All these minor streams must pass through the treatment plant, either directly or via No. 2 Reservoir before being returned to the environment.

After treatment, the effluent is delivered to one of five holding or monitoring ponds of 5000 m^3 each (1,100,000 Imperial Gallons). After analysis to assure the effluent meets the required regulations the effluent will be discharged to the environment via Wolf Lake. The regulations as set out by the AECB and the Saskatchewan Environment follow the regulations for mill effluents as outlined in the Fisheries Act with the exception of radium-226. For radium the AECB limit is 0.37 Bq/L (10 pCi/l) dissolved. Saskatchewan requires the same limit on total radium. In perspective the Federal Department of Health's drinking water standard is 1 Bq/L (27 pCi/L) for total radium.

To meet these strict regulations the solid tailing is neutralized with slaked lime ($Ca(OH)_2$). Lime is transported to the property as quicklime and slaked on-site using contaminated water from No. 2 Reservoir. To the neutralized tailing is added the solids from the water treatment plant and the whole pulp pumped to the tailing pond. This pond is some 650 metres (2160 ft. square) and has a capacity to hold the tailings until the year 2004 at the designed throughput. The tailing is laid down in layers over a bentonite base to produce an evenly dense mat with low permeability. Excess water is returned to No. 2 Reservoir for re-use or treatment.

The water treatment plant can treat in excess of 223.5 cubic metres/hour (864 Imperial Gallons/Minute). The water is neutralized by air agitation with a lime solution to a pH 12. This precipitates the heavy metals along with alumina, magnesia and iron from the raffinate, the solids are then removed by thickening. The thickener underflow is filtered and added to the solid tailing going to the tailings pond.

The clarified solution at pH 12 is then treated with barium chloride. Barium is chemically similar to radium and the alkaline earths. Barium and radium precipitate as sulphate along with gypsum ($CaSO_4$). These solids are removed by thickener and added to the solid tails. The clarified solution is then adjusted to a neutral pH with sulphuric acid which increases the sulphate content lowering the radium concentration still further. This precipitate is filtered under pressure and the clean solution sent to the monitoring pond where it is analysed to be sure it meets the required regulations. If the solution meets the regulations it is pumped to the environment by way of Wolf Lake and if not, it is returned to No. 2 Reservoir and re-processed. To date, operating of the system has been satisfactory.

4.8 MONITORING

All effluents must meet the licensing requirements before being released to the environment. In addition, both AECB and Saskatchewan Environment have requirements that Key Lake Mining Corporation must monitor the environment.

AECB requires effluents be analysed for arsenic, copper, lead, nickel, zinc, total suspended solids (TSS), pH and radium-226, and meet the discharge limits imposed on the company. In addition, on a three month interval Key Lake must conduct acute lethality tests on undiluted final effluent.

On a weekly and/or monthly basis the final effluent shall be analysed for iron, aluminum, magnesium, calcium, cobalt, sulphate, phosphate, silicate, ammonia, manganese, barium, sodium, chromium, selenium, chloride, fluoride, carbonate, potassium, bicarbonate, petrochemicals, uranium, thorium-230, polonium 210 and lead-210.

Discharge from the dewatering wells shall be monitored on a weekly basis for arsenic, copper, lead, nickel, zinc, radium-226 (total), uranium, TSS and pH.

In addition Saskatchewan Environment requires "as much clean water as possible shall be diverted away from areas of the project where contamination could occur". They also require monitoring of camp sewage, McDonald Lake, Outlet Creek, Wheeler River, Russel Lake, McDonald Creek, Raven Lake, Springs South-West of Wolf Lake, Delta Lake, Martin Lake Outflow, Downstream of David Creek, David Creek, potable water supply, Northeast Lake, Northwest Lake, Kirchner Lake, Black Forest Lake.

Saskatchewan Environment also require monitoring of on-site locations, tailing pond supernatant recovery water, tailing pond seepage, No. 1 and 2 Reservoirs, tailing area piezometers, reservoir piezometers, stockpile seepage collection systems. Air monitoring is required for sulphur dioxide and radon, plus radionuclides on the yellowcake dryer stack emission.

Saskatchewan Environment also requires aquatic biota and sediment monitoring in the water system plus soil and terrestrial biota monitoring.

This is a most comprehensive plan which will also supply valuable information to the uranium industry in general.

5. SPILLS

The spills reported to Saskatchewan Environment prior to and since start-up are tabulated in Table 1. They are of two basic types.

5.1 CONTAMINATED WATER FROM THE MINE

Contaminated water from the mine which is non-acidic but would contain radium-226. There was one spill of this type during the transfer of contaminated water from the holding Reservoir No. 1 to the tailing pond so repairs could be made to the pond liner. This occurred between July 22 and August 2. Because it was feared ice lenses would form in the tailing pond, the water was pumped back to the reservoirs. The details are set out in Key Lake's letter of December 6, 1983.

> "This letter describes several spills that occurred at Key Lake this past summer in connection with the use of a provisional pipeline that ran from the tailings management facility to the contaminated water storage reservoirs. Cleanup activity is also described.
>
> Between July 22 and August 2, contaminated water was pumped from the water storage reservoirs to the tailings management facility. This was done as a temporary measure to allow repair work and liner replacement to be undertaken on the reservoirs. During the pumping, several leaks were found, all but one of which were repaired immediately. One leak point could not be repaired, so a trench was excavated and lined with bentonite to catch the leakage. The contaminated water was removed from the trench periodically and disposed

TABLE 1

SPILLS

	DATE	LOCATION	MATERIAL	VOLUME M^3	VOLUME IMP.GAL.	REMARKS
1	Between July 22nd and Aug. 2, 1983	Provisional Pipeline between tail ponds and Reservoir	Contaminated water - neutral	a)385 m^3 b)57m^3/day for 12 days	84,700	A large part was collected in bentonite lined pond and transferred to ponds by tanker.
2	Dec. 4, 1983	Solution Pretreatment	Pregnant Soln. Acidic	4.5	1,000	
3	Dec. 23, 1983	Primary Thickener (CCD Area)	Pregnant Soln. Acidic	1.6	350	During Power Failure
4	Dec. 24, 1983	Solution Pretreatment	Pregnant Soln. Acidic	1.1	250	Pressure Switch Failure
5	Dec. 31, 1983	CCD	Pregnant Soln. Acidic	9.1	2,000	During Shutdown
6	Jan. 3, 1984	CCD	Contaminated Water-Acidic	1.1	250	Operator Problem
7	Jan. 7, 1984	Solution Pretreatment	Pregnant Soln. Acidic	0.5	100	" "

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of in the tailings management facility. During the eleven days of pumping an estimated 385 m^3 of contaminated water was spilled into the trench. This spill was reported to Saskatchewan Environment, Land Protection Branch in August. Since further use of the pipeline was anticipated no cleanup was attempted at that time.

Between August 25 and September 6 contaminated water was pumped from the tailings area back into the reservoirs. Because the reservoirs could not accommodate all the water in the tailings, pumping was stopped before the tailings area was completely pumped out. During the pumping 5 leaks were found which yielded an estimated 57 m^3/day combined leakage. Two major leak points were located; one was near the reservoirs, the other was at the same spot where the previous leak had been encountered. The leaks occurred at the couplings of the pipe sections, presumably because of faulty seals. One section of pipe which leaked particularly profusely was a newly placed section which had been carefully checked prior to pumping. Repairs were tried with tape and pieces of hypalon but these patches had little effect. One of the two major leaks and one minor leak were diverted into the ditch that had been used before that was lined with bentonite and hypalon. This trench was pumped out almost every day. The other leaks drained directly to the environment. These spills were reported to Saskatchewan Environment, Mines Pollution Control Branch in September. A written report of the spill was not

sent to Saskatchewan Environment; instead it was agreed KLMC would send a final report describing all the spills when the provisional pipeline was dismantled (cf. October 4 letter from Barsi (Saskatchewan Environment) to Courtney (KLMC).).

In October the provisional pipeline was dismantled. On October 31 the spill recovery pit was excavated and the contaminated material was disposed of at the special waste area. The area was then backfilled and covered over with clean fill. A general gamma survey was done after the cleanup of the spill area using a Victoreen 470 meter. This survey indicated no significant gamma contamination. It was felt, however, that this gamma survey needed to be redone using a more sensitive meter. KLMC's more sensitive PRM-7 gamma meter was being calibrated at the time and was not available for use until November 30.

On November 30 a gamma survey of the provisional line was done using the PRM-7 meter. A previous survey of this area had identified background gamma levels between 0.011 and 0.040 mR/hr (see August 25 letter from J. C. Anderson to R. R. Sentis: sample numbers 59 to 69 inclusive). In the November 30 survey the levels ranged between 0.013 and 0.018 mR/hr."

The clean-up results show gamma radiation is practically background. Because this water existed naturally in contact with the ore at the bottom of a lake and any losses were into a nearby bog which would ion exchange bivalent ions like radium, no migration of these ions should occur.

5.2 ACIDIC SOLUTION SPILLS IN MILL

A review of Table 1 shows there are only two areas that have suffered spills. One, the CCD section, the other the solution pretreatment section ahead of solvent extractions.

The CCD section spills have all been overtopping of the tanks. These are basically operating errors which should be eliminated as crews become more experienced. To attack the problem immediately, high level alarms have been installed. The company will install overflow pipes on the CCD thickeners. The company has a training program that is good and being upgraded by adding the latest video training equipment. The final answer will be operating experience, gained by the crew in anticipating trouble.

The other three spills took place in the solution pretreatment section. The total volume was only 1350 gallons or less than one gallon/minute for a single day in a stream operating at a liquid flow rate of 486 Imperial gallons/minute.

The operators have installed an elbow to direct drainage from tanks to the sump. The metallurgical staff have rewritten the computer program to prevent two pressure filters from regenerating at the same time or within thirty minutes of completion of a regeneration cycle. The company plans to raise the sill of the man door and examine the possibility of raising the sill of the service door. This latter will have to be co-ordinate with laying the asphalt apron.

In all acidic spills the presence of the asphalt apron around the mill buildings draining to No. 2 Reservoir would have prevented spilled material from escaping to the environment.

All these spills have frozen and the frozen material dug up and placed in the special waste area. All areas were checked for γ radiation and found to be just above background.

The spills listed in Table 1 have been reported as follows:

2. 9:00 a.m. December 4, 1983 in N.E. corner of SX building, approximately 1000 gallons of pregnant solution flowed through the door. The cause was an emergency shutdown of the reactor clarifier. The spill area was compacted fill of which 20 cubic yards have been removed to special waste area and replaced by fresh sand. An elbow is being installed to direct flow from the clarifier to sump.

3. December 23, 1983, 350 gallons of pregnant solution overflowed the primary and No. 2 CCD thickeners during a shutdown. High level alarms are now being installed and in spring, overflow pipes will be installed to direct this type of spill to the thickener corridor.

4. December 24, 1983, 250 gallons flowed through a door when a pressure switch on one precoat filter malfunctioned and allowed two precoat filters to discharge at one time. The computer program has been rewritten to prevent two precoat filters from discharging at the same time.

5. December 31, 1983, 2000 gallons of pregnant solution overflowed No. 2 CCD tank during a shutdown. This spill is similar to No. 3 above and will be addressed in the same way.

6. January 3, 1984, 250 gallons of contaminated water overflowed No. 8 CCD tank. See spills 3 and 5 above.

7. January 7, 1984, 100 gallons of pregnant solution when two precoat filters went into regeneration mode at one time. See also spill 4 above. Computer program is now in place (Feb. 6, 1984).

6. SITE STAFFING

Key Lake Mines opted to operate their mine and mill on a "fly-in, fly-out" basis where employees are on-site 7 days and out 7 days. The management and staff on-site are housed in a 300 bed complex complete with excellent dining and recreation facilities. It is a condition of Key Lake's land lease that fifty-one percent of the company employees in the first year be Northeners rising to sixty percent in year two. Key Lake began hiring experienced staff and training operators two years priors to start-up. The depression throughout the rest of the mining industry favoured Key Lake.

From the beginning, Key Lake has employed a training supervisor and used models of the plant to teach even experienced operators the geometry of a new plant. This will be supplemented shortly by a new video technique. None of these systems will completely replace learning by experience, the need to see the level of a thickener tank on a night when sub zero temperatures produce clouds of water vapour is only learned by "hands on" training. High level alarms now being installed will help the operator learn.

At any one time there is a member of senior management on-site. The mill supervision consists of a superintendent, two foreman, two assistant foreman and two process supervisors on-site. These men work what is called an 11 hour shift. Actually, the shift is twelve hours with one hour for dinner or lunch, which is served at the living complex. This means the plant is covered 24 hours a day. All staff members are on call.

The shifts themselves are adequately covered by personnel, starting with a control room operator who is responsible to the foreman and process supervisor, the senior leach operator on the floor who has under him, second class operators for the various circuits.

The plant is highly instrumented and to maintain and service these instruments, each shift has four instrument men and one electrician. This will be increased to six instrument men. All personnel operate on the 11 hour/day basis which means the plant is covered 24 hours a day.

During the author's visit the plant was extremely clean and well maintained. Supervision appears to be making every effort to maintain this high state of cleanliness. All mills change and modify their operating procedures as experience develops and Key Lake will be no exception. The inplant spills to-date would be considered minor in most mills.

7. AUXILLIARY SERVICES

7.1 SULPHURIC ACID MANUFACTURING PLANT

Sulphuric acid for the metallurgical plant and pH adjustment of the neutralization circuit is manufactured on-site in a 200 ton per day sulphuric acid plant. The sulphuric acid is produced by the burning molten sulphur which is brought by tanker to the plant. The sulphuric acid plant is a double absorption system capable of producing 94% sulphuric acid which is distributed throughout the plant in insulated lines from 2 x 1000 ton storage tanks contained with the usual engineered dykes to contain the acid in the event of a tank rupture. Sulphuric acid can be regarded as a hazardous chemical and not a pollutant because the neutralization of sulphuric acid produces calcium sulphate, better known as gypsum the product contained in wallboard.

The burning of sulphur produces large amounts of waste heat which Key Lake recaptures as high pressure steam used to produce electricity through a turbine and for heating purposes throughout the plant. It is interesting to note that all the utilidors throughout the plant are heated to a comfortable temperature by means of these steam pipes.

7.2 ELECTRICAL POWER

Key Lake, because of its remote location generates its own power using five 2.1 megawatt Merrilees diesel engines which are located in the main power plant. The fact that there are five machines allows regular maintenance to be carried out without interruption of the power supply.

In the event of the whole plant going off-line at any one time, the plant is backed up by two-600 kilowatt Caterpillar stand-by diesels which will power such items as the rakes in the thickeners,

air compressors to provide air for agitation in the pachucas and in the air lifts throughout the CCD circuit so that the sand loads can be removed from the thickeners and sent to the tailing pond.

7.3 LIME HANDLING

The lime is imported to the property as "quick lime" hauled by lime haulers trailing one pup. The quick lime is stored in three lime silos with the usual lime silo dust collection units on the top. The silos discharge to paste lime slakers and the hydrated lime stored as a slurry. The grit and unslaked lime is caught in tote boxes, picked up and taken to the special material storage area. This material is available to neutralize any spill of acidic material if, as and when required.

7.4 OXYGEN PLANT

Compressed air in the pressure leachers will be replaced by oxygen when the oxygen plant comes on stream this summer.

8. UNCOMPLETED WORK AND MODIFICATIONS PLANNED

The following uncompleted work and/or modifications to the original design are as follows.

8.1) Repairs to the dyke around No. 2 Reservoir and repair to the liner are underway under the direction of Key Lake's geotechnical engineering consultant. It is estimated that this repair will be completed by March, 1984.

8.2) One major program has to be completed and that is to place the tarmac apron around the mill proper.

This tarmac will surround the operating buildings and slope towards No. 2 Reservoir. In the event of spills such as those that have taken place around the mill building, the drainage will be to No. 2 pond and the tarmac can be hosed down. The area has been compacted and is ready for the laying of asphalt this spring. It is estimated that this work can start in May and it will take approximately one month.

8.3) A similar apron will be placed around the grinding plant. Spills in this area would normally be of ore and be of a neutral, not acid, condition and therefore, would be swept up and the remainder washed into the contaminated water lines going to No. 1 Reservoir. This area requires some fill and grading. It is estimated to take about 2 weeks to place the fill and another two weeks to place the tarmac.

8.4) Oxygen Plant

The oxygen plant will come on-stream this summer and in the meantime, compressed air will be utilized to oxidize the iron salts in the pressure leach. This is solely and operating situation and not one that would in any way pollute the environment.

8.5) Relatively major modifications will be made to the grinding plant with the addition of a semi-autogenous (SAG) grinding mill. This grinding mill will take -18" material thereby eliminating the impact crusher and much of the problems connected with the handling of clayey ores. The present ball mill will be used as a regrind mill if it is required.

8.6) There will be other improvements and modifications made as time goes on. One is the raising of one or two door sills to increase the volume within the building. Another, a curb in the CCD corridor to protect a door to an electrical control room. It is now planned to put overflow pipes on the launders of the CCD thickeners and drain them to the corridor thereby obviating completely the possibility of a spill into the yard by overtopping the thickener.

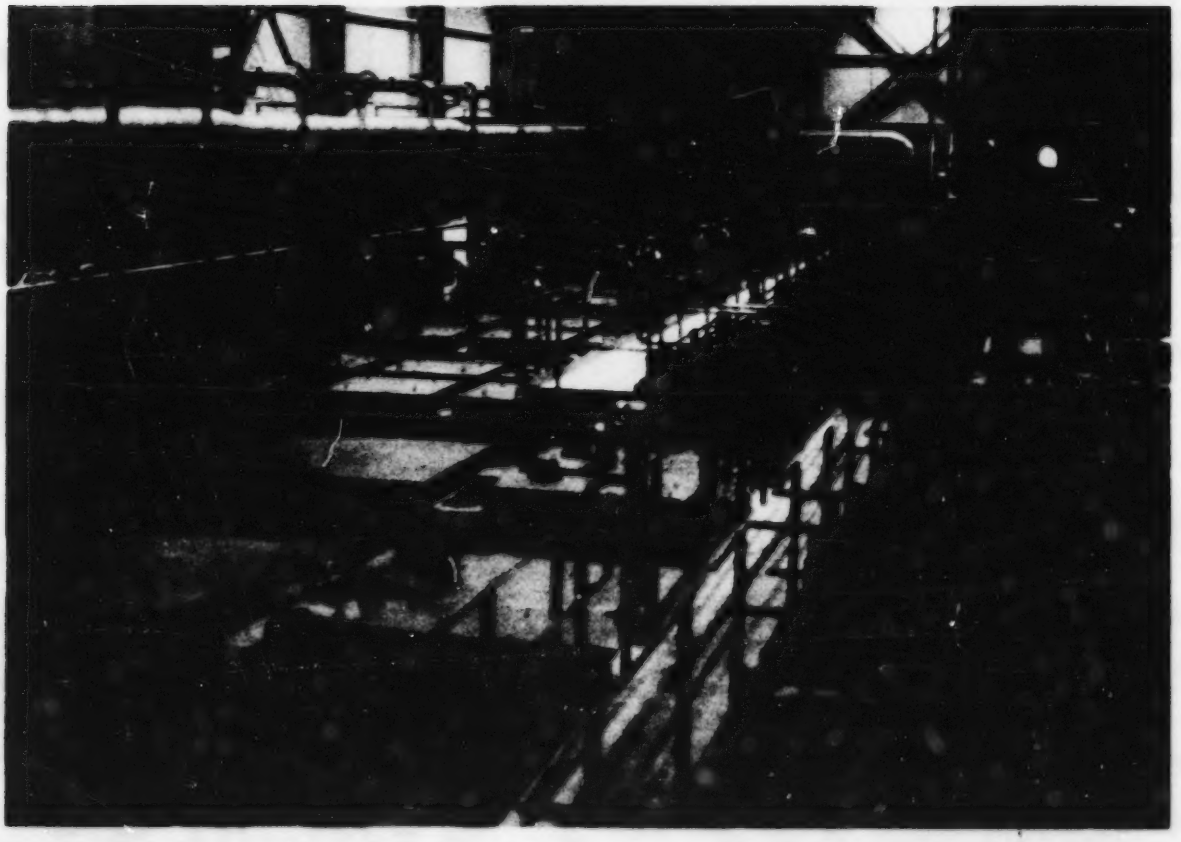
9. PHOTOGRAPHS

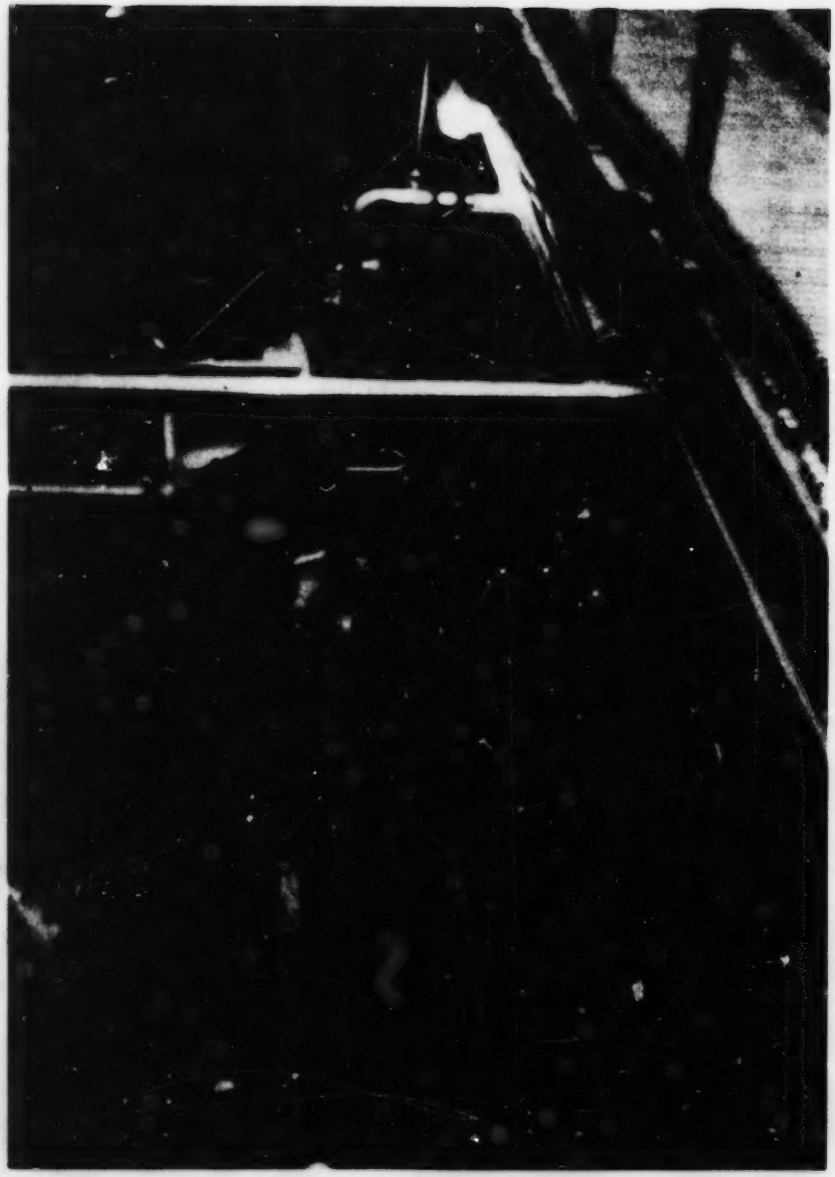
No. 1 View of metallurgical plant taken from the road to the tailing pond. Tailing pond berm is on the left. Note clouds of water vapour off CCD thickeners.

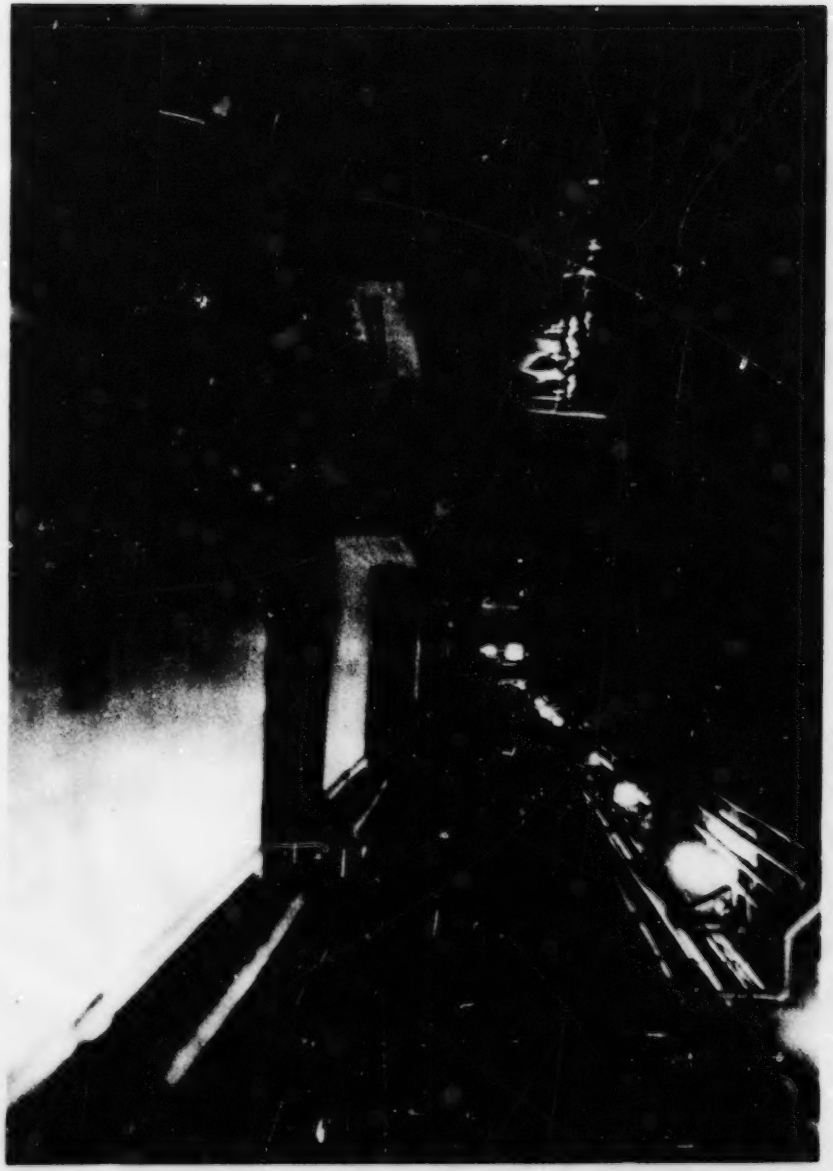
No. 2 Solvent extraction section showing housekeeping of upper floors.

No. 3 CCD corridor showing typical housekeeping in operating areas.

No. 4 Sumps in lime slaking area.







POOR

QUALITY

ORIGINAL